Physical and Biological Effects on Tide Flat Sediment Stability and Strength

Robert A. Wheatcroft
College of Oceanic and Atmospheric Sciences
Oregon State University
Corvallis, OR 97331
phone: (541) 737-3891 fax: (541) 737-2064 email: raw@coas.oregonstate.edu

Award Number: N00014-08-1-0954

LONG-TERM GOALS

The ultimate goal of this research is to better understand the physical and biological processes that control the erosion, transport and deposition of fine-grained sediment in marine environments by collecting high-resolution field data that is compared to simple models.

OBJECTIVES

This research is part of the Tidal Flats Department Research Initiative (DRI) that is focused on understanding the controls of sediment strength over multiple time and space scales on the mud flats of Willapa Bay, Washington. My role in the DRI is to: (1) obtain high-resolution profiles of sediment bulk density to compare against erodibility measured by other investigators, and (2) collect data on surficial particulate organic carbon content and chlorophyll-*a* concentration. The latter are both proxies of exopolymeric substances (EPS), which are known to affect sediment erodibility.

APPROACH

Our approach in the DRI has been to exploit the strong seasonality in physical forcing that exists on the Willapa Bay mud flats to better understand sediment erosion and deposition and the development of seabed strength. Thus, we have focused on making measurements during two parts of the year (March vs. July) that have important differences in key forcing variables (e.g., solar insolation, rainfall, wind waves, sea grass cover). Measurements have been mostly focused in and around a secondary, 5-m wide channel ("C-channel") that drains a portion of the Willapa Bay mud flat (Fig. 1). There, a series of stations have been occupied on the adjacent flats (B and C) and at various points across and along the channel itself.

My measurements have been focused on acquiring a high-resolution data set on seabed strength. In particular, an autonomous sediment profiler (ASP) (Wheatcroft et al., 2007) was deployed for two 10-d periods at the mouth of the channel. ASP consists of a 4-electrode resistivity probe that is moved in three dimensions (~50 cm vertical & 20 cm by 100 cm in the horizontal) in programmable time and space patterns. Through empirical calibrations, ASP yields highly resolved (1-mm vertical interval; 15-minute sampling interval) profiles of bulk density (=porosity) of the upper 20 cm of the seabed,

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE **Physical and Biological Effects on Tide Flat Sediment Stability and Strength**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Oregon State University,College of Oceanic and Atmospheric Sciences,Corvallis,OR,97331**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

thereby providing unique *in situ* data on sediment consolidation and deconsolidation, as well as small-scale variability. Second, co-located measurements of sediment porosity and erodibility using a portable In situ Resistivity Profiler (IRP, Wheatcroft, 2002) and a Gust chamber (Stevens et al., 2007), respectively, were made at each station. By coupling the erodibility results to the much more easily obtained porosity data, it has been possible to map seabed erodibility over larger spatial domains, which is a necessary first step toward initializing and testing models of tide flat morphology. In addition to the porosity and erodibility measurements, surficial measurements of total organic carbon chlorophyll *a* were made at a large number of sites within the southern Willapa Bay environment.

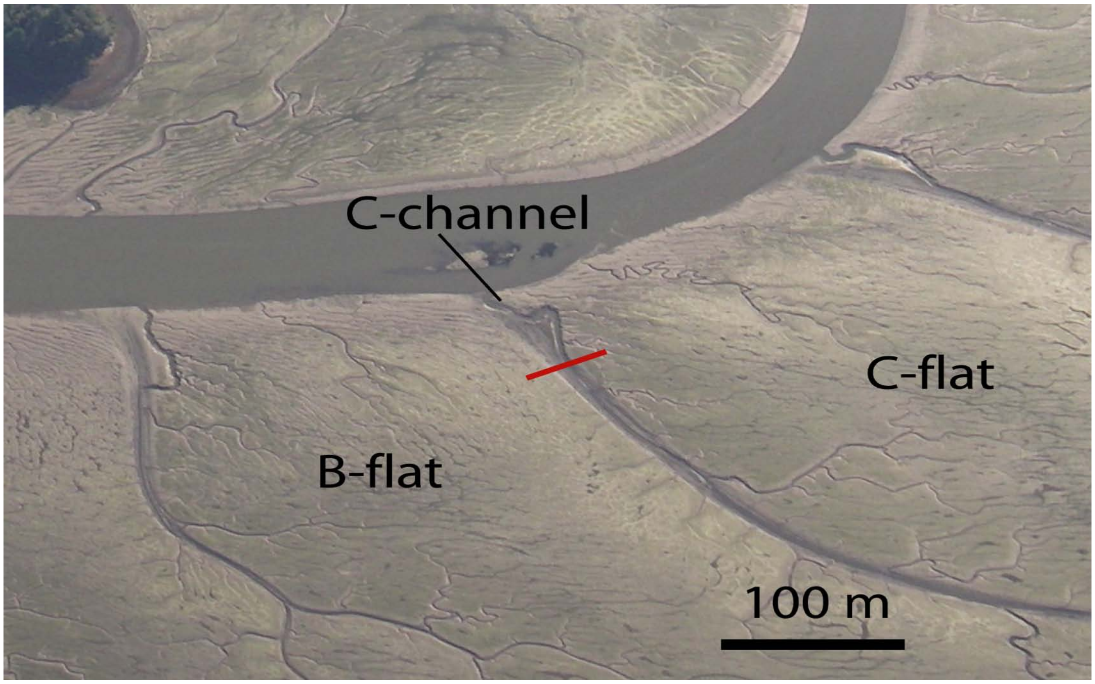

Fig. 1 Aerial photograph of a ~500-m square part of the Willapa Bay mudflats (courtesy of J. Thomson, APL-UW) showing the location of the B and C flats and C-channel. The diagonal red line marks the location of a cross-channel transect where multiple measurements of erodibility, seabed strength, grain size and TOC were made in March and July 2009.

WORK COMPLETED

During FY-09, the PI and his lab technician, Ms. Rhea Sanders, were involved in two 14-d long field campaigns (in March and July) at the Willapa Bay study site (Fig. 1). Activities during these field efforts were fourfold. First, the autonomous sediment profiler (ASP) was deployed and recovered each time. (Unfortunately, salt crystal formation on the instrument's guide rails, coupled with abundant flotsam, which fouled the instrument, severely compromised performance and few data were acquired.) Second, the in situ resistivity profiler (IRP) was used to collect roughly 100 high-resolution profiles of sediment porosity at multiple sites within the tide flat complex during each field campaign. Third, samples were collected at a variety of sites for lab analyses of total organic carbon and chlorophyll-a (a proxy for exocellular polymeric substances). Fourth, extensive field support, in the form of a small boat, was provided to other DRI investigators. Processing of the IRP data and laboratory analyses of the TOC and chl-a samples are ongoing.

RESULTS

There are several preliminary findings. First, there are clear seasonal differences in important forcings, such as insolation, rainfall, benthic microalgae and sea grass abundance that are operating in a predictable manner (i.e., our basic ideas about forcing on the Willapa flats seem to be essentially correct). Thus, during the wintertime there was a pronounced difference in the seabed strength of the flats vs. channels, with the former considerably more consolidated and reminiscent of a 'stress hardened' bed (sharp porosity profile). This pattern likely arises from low sediment retention on the flats, which is due to elevated wind-wave stresses, rainfall effects and absence of microalgae/sea grass. Second, there is evidence that on spatial scales of meters and time scales of days variability on the flats is small compared to that observed in the channels. Lastly, and related to point 2, the channels show interesting variability that may be tied to movement of dense suspensions of mud (Fig. 2). The significance of these findings is that because many of the important forcings (e.g., rain fall, insolation, sea grass cover) can be measured remotely, there is the possibility that first-order predictions of tide flat strength can be made from relatively simple measurements.

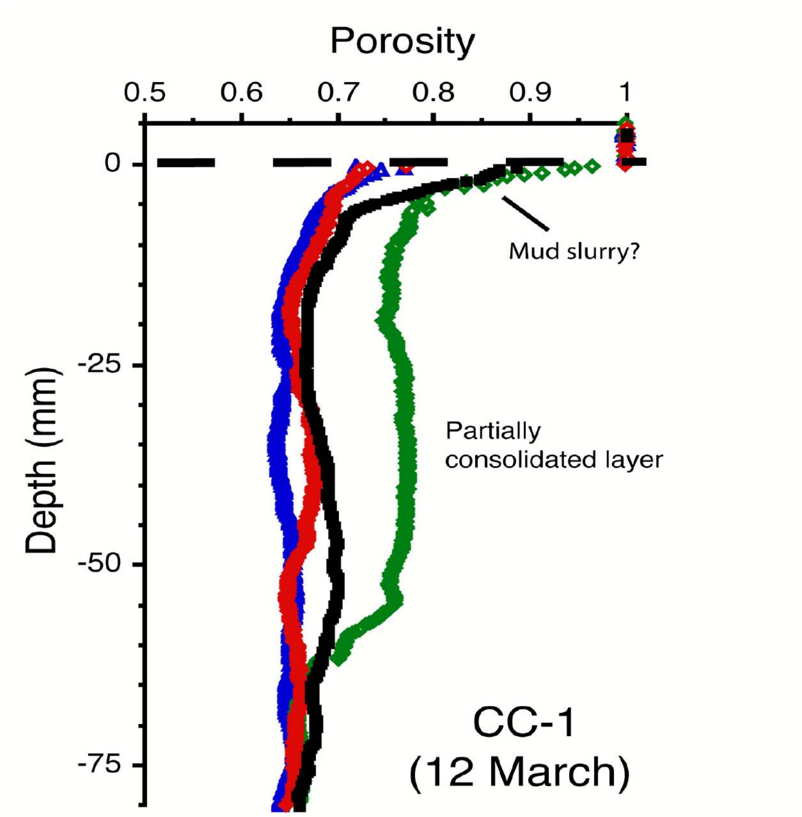

Figure 2. High-resolution, in situ porosity profiles collected near the center of C channel. All profiles were collected within an area 2 meters in diameter, but there is substantial variability in the upper 5 cm of the bed. Two profiles (black and green) show evidence of a thin (~5 mm) layer of low strength sediment (porosity > 0.80) that may be a mud slurry, whereas 2 profiles (blue & red) do not (porosity <0.7). In addition, the green profile shows evidence of a 50-mm thick partially consolidated bed that is >10% higher porosity than ambient.

IMPACT/APPLICATIONS

In temperate mud flats, it may be that seasonal variation in important forcings, such as rain fall, solar input, and aquatic vegetation – all of which can be measured remotely – control the strength of the sediment. If this simple idea proves correct, then it may be possible to predict mud flat trafficability from known quantities.

RELATED PROJECTS

This effort is closely related to those of several other DRI investigators. In particular, Pat Wiberg (U Virginia) provides measurements of sediment erodibility that are extended by my porosity measurements. Other collaborators are Paul Hill (Dalhousie U) and Tim Milligan (BIO) who are focused on determining patterns of sediment erosion and deposition mainly from a water-column perspective. Chuck Nittrouer (UW) is making independent measurements of seabed accretion and erosion, as well as documenting subsurface fabric. Lastly, the geotechnical measurements being made by Bruce Johnson (Dalhousie) extend and are enabled by my measurements of bulk density.

REFERENCES

Stevens, A. W., R. A. Wheatcroft and P. L. Wiberg. 2007. Seabed properties and sediment erodibility along the western Adriatic margin, Italy. *Continental Shelf Research* 27: 400-416.

Wheatcroft, R. A. 2002. *In situ* measurements of near-surface porosity in shallow-water marine sands. *IEEE Journal of Oceanic Engineering*, 27: 561-570.

Wheatcroft, R. A., R. V. Johnson and A. W. Stevens. 2007. *In situ* time-series measurements of subseafloor sediment properties. *IEEE Journal of Oceanic Engineering* 32: 862-871.